From the Western Vascular Society

Thoracic outlet syndrome in high-performance athletes

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Objective: **Repetitive upper extremity use in high-performance athletes is associated with the development of neurogenic and vascular thoracic outlet syndrome (TOS). Surgical therapy in appropriately selected patients can provide relief of symptoms and protection from future disability. We sought to determine the incidence and timing of competitive athletes to return to their prior high-performance level after TOS treatment and surgery.**

Methods: **We reviewed all competitive high school, collegiate, and professional athletes treated for venous or neurogenic TOS (nTOS) from 2000 to 2012. Patient demographics, workup, and treatment approaches were recorded and analyzed. Patients with nTOS were assessed with quality of life surveys using the previously validated 11-item version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) scale, scored from 0 to 100 (100 = worse). Return to full athletic activity was defined as returning to prior competitive high school, collegiate, or professional sports.**

Results: **During the study period, 41 competitive athletes (44% female) with a mean age of 19 years, were treated, comprising 13 baseball/softball players, 11 swimmers, 5 water polo players, 4 rowers, 2 volleyball players, 2 synchronized swimmers, 1 wrestler, 1 diver, 1 weightlifter, and 1 football player. Twenty-seven athletes (66%) were treated for nTOS, and 14 (34%) had Paget-Schroetter syndrome (PSS). All PSS patients underwent typical treatment of consisting of thrombolysis/anticoagulation, followed by first rib resection. Most nTOS patients were treated according to our previously reported highly selective algorithm, beginning with TOS-specific physical therapy (PT) after the clinical diagnosis was made. Because of mild to modest symptom improvement after PT, 67% of the nTOS athletes evaluated ultimately underwent supraclavicular first rib resection and brachial plexus neurolysis. Return to full competitive athletics was achieved in 85% of all patients, including 93% of the PSS patients and 81% of the nTOS athletes, at an average of 4.6 months after the intervention. In the nTOS cohort successfully returning to prior sports ability, seven (32%) were treated only with PT. Of those athletes who underwent surgery for nTOS, 83% returned to full competitive levels. QuickDASH disability scores improved from a mean of 40.4 preoperatively to 11.7 postoperatively, indicating significant improvement in symptoms after treatment. Recurrence of symptoms was noted in two nTOS (7%) and two PSS (14%) athletes.**

Conclusions: **Standardized treatment algorithms for venous and nTOS and aggressive TOS-specific PT are key components to optimizing clinical outcomes in this special cohort of TOS patients. Most athletes treated for venous and nTOS can successfully return to competitive sports at their prior high-performance level. (J Vasc Surg 2014;60:1012-8.)**

Thoracic outlet syndrome (TOS) typically presents as upper extremity symptoms caused by compression of the neurovascular structures in the area of the neck above the first rib. Clinical manifestations can include upper extremity pain, paresthesias, numbness, weakness, fatigability, swelling, discoloration, and Raynaud phenomenon. TOS may result from a variety of anomalies, including cervical ribs, fascial bands, and abnormalities of the origin or insertion of the anterior or middle scalene muscles.[1] Repetitive upper extremity use, as can be seen in high-performance overhead athletes, can be associated with the development of vacular TOS and neurogenic TOS (nTOS).

Symptoms from nTOS are due to compression, irritation, and chronic overuse injury of the roots of the brachial plexus, specifically within the scalene triangle at the base of the neck or within the subpectoral space immediately inferolateral to the clavicle, or both. Repetitive overhead motions and exercise exhibited by athletes may lead to loss of shoulder girdle stability and hypertrophy or imbalance of the anterior/middle scalene muscles or pectoralis minor muscle, or both, all of which contribute to the development of nTOS. Athletes might be at even higher risk given the relative amount of musculature developed in training.

Vascular TOS can involve the subclavian artery or vein, although much less common than nTOS. Arterial TOS, which is incredibly rare, can cause subclavian artery aneurysm with associated thrombus and distal embolization.[2,3] Chronic injury and compression of the subclavian vein between the clavicle and first rib and nearby subclavius tendon increases the risk of effort thrombosis, also known as Paget-Schroetter syndrome (PSS). PSS is also a relatively uncommon condition, far less common than nTOS, but is described more frequently in young competitive athletes.[4,5]

Competitive athletes comprise a distinct patient population that has not only a higher predisposition to the development of TOS but also high physical performance demands and substantial pressures to achieve a rapid return to previous levels of physical performance after being

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injured. Disability and postintervention recovery related to TOS treatment and possible surgery can have a significant effect in their overall performance abilities, and little has been published specifically about the ability of athletes to recover after TOS. The purpose of this study was to evaluate the ability and timing of competitive athletes to return to their prior high-performance level after TOS treatment and surgery.

METHODS

We reviewed all competitive athletes treated at our institution for vascular or nTOS from 2000 to 2013. Approval for the project was obtained from our Institutional Review Board and informed consent was obtained for all patients. Competitive athletes at the time of presentation were defined by active participation in organized individual or team sports at the varsity high school, National Collegiate Athletic Association (NCAA) collegiate, or professional or semi-professional levels, as reported by the patients and verified by team records or discussions with coaches. The study excluded recreational athletes evaluated for TOS at our institution.

All athletes referred for evaluation of nTOS from 2000 to 2007 ultimately underwent surgery and were included in the analysis. Most patients exhibited typical upper extremity discomfort, paresthesias, and symptomatology, and during this earlier period were offered surgical decompression if results of electromyelography studies, orthopedic evaluation, and spine evaluation were indicative of nTOS.

Since 2007, we have implemented a prospective highly selective treatment algorithm, previously published,[6] that uses response to TOS-specific physical therapy (PT) as a main predictor of surgical success. Athletes evaluated from 2007 to 2013 were included in this current analysis. This treatment algorithm included documentation of quality of life scores using the validated 11-item version of the Disabilities of Arm, Shoulder and Hand (QuickDASH) questionnaire (QD), which is scored from 0 to 100 (100 = worse), duplex imaging of the thoracic outlet, and mandatory TOS-specific PT designed to mimic relaxation of the thoracic outlet.[7-9] The QD scale is a validated survey specifically designed to measure physical function and disability in persons with musculoskeletal disorders of the upper limb. In addition, it has a module focused specifically on high-level performance for athletes or performing artists, with questions documenting the degree of disability associated with their particular sport or activity.[8]

Patients since 2007 were then offered decompressive surgery based on some response to PT and improvement in symptoms, and those with no response or worsening symptoms with this specific PT were believed to have other syndromes and not likely to improve with TOS surgery. All nTOS patients offered surgery underwent a standardized supraclavicular approach to decompression, anterior and middle scalenectomy, complete rib resection, and extensive brachial plexus neurolysis.

Vascular TOS patients treated from 2000 to 2013 were also identified and included in this study. No competitive athletes with arterial TOS were found during the study period, and therefore, all athletes with vascular TOS presented with effort thrombosis. PSS athletes were most often treated with thrombolysis before surgical decompression of the thoracic outlet, along with adjunct venoplasty at the time of rib resection or after, depending on recurrent symptoms. No open venous reconstructions were performed, although extensive venolysis was used to free up external scar tissue. All PSS patients underwent an infraclavicular, supraclavicular, or paraclavicular approach to decompression based on muscular bulk and to safely visualize the injured vein and subclavius tendon.

Detailed information for each patient was summarized from the electronic medical record review. All athletes were also contacted by phone or e-mail in the summer of 2013 and asked to participate in a follow-up survey, which included questions about timing and degree of return to competitive sport, current and previous symptoms, and most recent QD scores.

The primary outcome measure was return to full athletic activity, defined as competing postoperatively to the prior level of high school, collegiate, or professional sports. The duration of recovery, incidence of recurrence, and complications were also recorded and analyzed. Data were collected and statistical analyses performed using Excel 2010 software (Microsoft Corp, Redmond, Wash). Paired *t*-tests were used to determine differences between the QD disability scores before and after PT, as well as preoperatively and postoperatively. The Wilcoxon rank sum test or Fisher exact test were used to test for statistical differences between groups, where appropriate, with values of $P < .05$ considered significant.

RESULTS

During the study period, 41 competitive athletes underwent evaluation or surgical treatment for all forms of TOS; of those, 66% were nTOS patients and 34% were PSS patients. Demographic information is reported in Table I, with the athlete cohort consisting of 23 male (56%) and 18 female (44%) athletes, with a mean age of 19 years (range, 13-36 years). Seven patients (17%) were professional athletes, 16 (39%) participated in collegiate sports, and 18 (44%) participated on high school teams (Fig 1). The patients participated in the following sports: baseball, 13; swimming, 11; water polo, 5, rowing, 4; volleyball, 2; synchronized swimming, 2; wrestling, 1; diving, 1, and football, 1. Patients being evaluated for nTOS exhibited pre-evaluation symptoms for a mean of 11 months, whereas PSS athletes were sidelined from their sport for a mean of 1.6 months before surgical evaluation.

nTOS patients. Treatments and clinical outcomes for 27 athletes with nTOS are reported in Table II. Nine (33%) were treated nonoperatively with only TOS-specific PT, and 18 (67%) underwent operative decompression. There was no predilection towards the right or left arm, and also none to the dominant arm. Postoperative complications included one hemothorax requiring video-assisted

Table I. Demographics of competitive athletes with neurogenic thoracic outlet syndrome (*nTOS*) and Paget-Schroetter syndrome (*PSS*)

Variable[a]	*All (N = 41)*	*nTOS (n = 27)*	*PSS (n = 14)*
Age, years	19.0 (13-36)	19.0 (14-32)	18.8 (15-24)
Female	18 (44)	17 (63)	1 (7)
Sport			
Swimming	11 (27)	11 (41)	0 (0)
Baseball	13 (33)	4 (14)	9 (65)
Synchronized swimming	2 (5)	2 (7)	0 (0)
Volleyball	2 (5)	1 (4)	1 (7)
Rowing	4 (10)	3 (11)	1 (7)
Football	1 (2)	0 (0)	1 (7)
Water polo	5 (12)	3 (11)	2 (14)
Weightlifting	1 (2)	1 (4)	0 (0)
Wrestling	1 (2)	1 (4)	0 (0)
Diving	1 (2)	1 (4)	0 (0)
Affected side right	26 (63)	14 (52)	12 (86)
Affected side dominant	28 (68)	16 (59)	12 (86)
Bilateral	1 (2)	1 (4)	0 (0)

[a]Continuous data are presented as the mean (range) and categoric data as number (%).

Table II. Treatment type and outcomes for competitive athletes with neurogenic thoracic outlet syndrome (*nTOS*) and Paget-Schroetter syndrome (*PSS*)

Variable[a]	*All (N = 41)*	*nTOS (n = 27)*	*PSS (n = 14)*
Treatment			
Operative	32 (78)	18 (67)	14 (100)
Nonoperative	9 (22)	9 (33)	0 (0)
Hospital stay, days	2.6 (1-12)	1.9 (1-6)	3.5 (1-12)
QD score			
Preoperative	40.4	40.4	–
Postoperative	11.7	11.7	–
Thrombolysis timing before surgery, days	84 (2-730)	–	84 (2-730)
Return to full sport	35 (85)	22 (82)	13 (93)
Time to pain free, months	2.7 (1-12)	3.4 (1-12)	1.9 (2-12)
Time to return to full sport, months	4.6 (1.5-12)	4.4 (1.5-6)	4.7 (2-12)
Post-op anticoagulation duration, months	2.3 (1-5)	–	2.3 (1-5)

QD, QuickDASH (11-item version of the Disabilities of Arm, Shoulder and Hand assessment).
[a]Continuous data are presented as the mean (range) and categoric data as number (%).

thoracoscopic surgically assisted decompression, one chylothorax requiring drainage, and one wound seroma.

Most patients undergoing operation stayed overnight and rapidly began postoperative PT consisting of range of motion and strengthening exercises. Trainers and physical therapists were instructed to gradually build up strength and range of motion in the immediate postoperative period and allow return to full use of the upper extremity at the 6-week to 8-week follow-up. The nTOS athletes were sidelined from their sport for an average of 11 months before surgical decompression and for 4.6 months after surgical decompression.

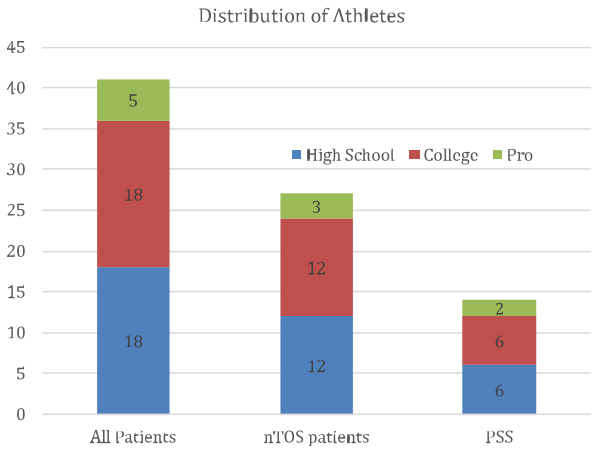

Fig 1. Distribution of athletes treated for neurogenic thoracic outlet syndrome (*nTOS*) and Paget-Schroetter syndrome (*PSS*).

The QD scores were obtained prospectively for 70% patients preoperatively and improved significantly, from 40.4 preoperatively to 11.7 postoperatively ($P = .02$), and had improved even more, to 6.8, at latest phone survey follow-up (mean follow-up, 37 months; range, 3-123 months; $P = .02$ compared with baseline; Fig 2).

In the nine patients who underwent TOS-specific PT only and ultimately did not have surgery, the baseline QD score was 37.4 and improved slightly to 30.3 after PT ($P = .14$). By following our algorithm with slight improvement, they were all offered decompression but chose, due to a variety of scheduling reasons (most often due to academic conflicts or scholarship requirements), to continue with PT or attempt to return to sport. At the latest survey follow-up, this "nonoperative" athlete cohort showed an improvement in mean QD score to 9.9 ($P = .03$ compared with baseline). Of note, these nine patients who ultimately improved without surgery and only with longer-term TOS-specific PT had a shorter duration of symptomatology before evaluation (3 months vs 15 months; $P = .006$) than those who had mild response to PT only and ultimately underwent surgery and improved after.

Of all 27 nTOS athletes evaluated, 22 (81.5%) successfully returned to full activity at or above their previous competitive level on their teams (Fig 3). The mean time to pain-free return of the nTOS patients undergoing surgery was 3.4 months, and the mean time to resumption of full sport/activity was 4.4 months after surgery (range, 1-12 months). According to their late survey responses, 89% of the nTOS athletes who had operations would choose surgery again.

Two athletes experienced symptomatic recurrence: one volleyball player after 24 months, who then retired from sport, and one after 6 months, from another shoulder pathology that effectively ended their athletic careers. One patient experienced entrapment of the supraspinatus nerve

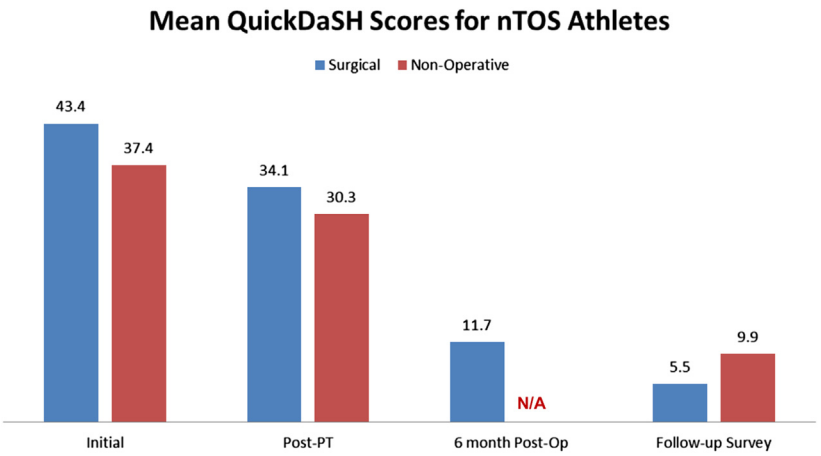

Fig 2. Improvement in the 11-item version of the Disabilities of Arm, Shoulder and Hand (*QuickDASH*; QD) score after treatment for neurogenic thoracic outlet syndrome (*nTOS*) in athletes. *N/A,* Not applicable; *PT,* physical therapy.

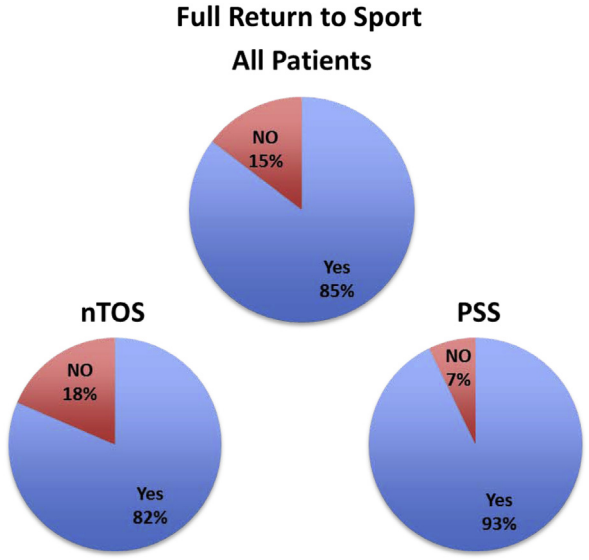

Fig 3. Percentage of athletes with neurogenic thoracic outlet syndrome (*nTOS*) and Paget-Schroetter syndrome (*PSS*) that returned to full athletic activity.

after surgery, which improved after surgical release but also resulted in retirement from collegiate swimming.

PSS patients. During the study period, 14 athletes underwent treatment for PSS. All patients initially presented with acute axillosubclavian vein thrombosis diagnosed on duplex imaging. Thrombolysis was administered to all but one patient (treated only with anticoagulation after initial presentation) their preoperative evaluation (range, 1-60 days after diagnosis). Nine patients (64%) had complete resolution of thrombus burden after thrombolysis, and the remainder had persistent partial thrombus burden. After initial anticoagulation/thrombolysis, all PSS athletes underwent first rib resection with subclavian vein venolysis, with six (43%) undergoing venoplasty during their TOS surgery to restore normal vein caliber and patency.

All but one PSS patient returned to full athletic ability (92.9% successful return to sport), with the mean pain-free follow-up time of 1.9 months, and return to full athletic activity at 4.7 months (range, 2-12 months; Fig 3; Table II). Two patients experienced hemothorax requiring video-assisted thoracoscopic surgical decompression. Subsequent to these complications, we altered our algorithm by holding repeat anticoagulation until 5 to 7 days postoperatively. Duration of postoperative anticoagulation averaged 2.3 months (range, 3 weeks-5 months).

On the long-term follow-up survey (mean, 34.5 months; range, 13-144 months), all patients indicated they would have done the surgery again, and the mean QD score (although not calculated preoperatively for comparison) was 5.8.

DISCUSSION

We have demonstrated in this series an 80% to 90% incidence of return to sport within 4 to 5 months in competitive athletes who presented with TOS and were aggressively treated. Although neurogenic symptoms untreated and undiagnosed can lead to nearly 1 year of disability from sport, TOS-specific PT and, ultimately, surgery both resulted in an 81% likelihood of return to sport. PSS athletes experienced even better outcomes, with most presenting more acutely and only 1 to 2 months of initial downtime, then 2 to 3 months postoperatively without pain, and 93% returning to full athletic function. Although many other factors beyond the surgeon's control dictate return to high school, collegiate, or professional sports, we believe that the need for surgery for TOS is not necessarily a career-ending diagnosis.

The careful selection of patients to undergo surgical decompression for nTOS cannot be overemphasized. As we reported previously,[6] a highly selective algorithm consisting of TOS-specific PT and offering surgery to those who exhibit modest improvement increased our success rates from 50% to 90%. It is no surprise that in this analysis, we were able to achieve similar results by applying that same careful algorithm to competitive athletes, with 81% returning to

full sport, which we would consider successful surgery. Although this somewhat counterintuitive algorithm discounts those athletes in whom PT fails, our experience has been that those patients do not improve dramatically with surgery.

Athletes in general present a challenging cohort to diagnose, and the delayed time of 11 months of symptoms seen in this series before evaluation for a possible workup is likely due to the extensive orthopedic workup from team physicians, the use of other types of PT, and still a relative lack of knowledge about TOS in general. The vigorous overhead use of the upper extremities required in most overhead sports predisposes high-performance athletes to a variety of neurovascular injuries, particularly TOS.[4] Outcomes of athletes treated for TOS, particularly nTOS, have been limited primarily to case reports and small series.[10-17]

The types of sport represented in our series are consistent with those reported in the literature. Specifically, the preponderance of baseball players, swimmers, rowers, and water polo players is related to their primary arm motion, which is related to arm abduction to 180°, pulling the shoulders down and back, or muscle swelling from trauma, exercise, or hypertrophy of the trapezius, scalene muscles, or pectoralis minor.[18,19] Other reports have identified nTOS in tennis players, weightlifters, football players, and wrestlers.[14,20-22]

With the same risk factors for nTOS, athletes that develop PSS are in a high-risk cohort as a consequence of exertional activity with the arm in elevation, combined with underlying anatomic constraints at the level of the first rib, including hypertrophy of the underlying anterior scalene muscle. The pathophysiology from the chronic overuse of the upper extremity seen in athletes is related to initial positional injury to the subclavian vein that stimulates the formation of fibrosis within and around the vein wall. Repetitive cycles of injury and repair lead to the development of venous collateral vessels along with constricting scar that gradually narrows the subclavian vein. This process, which may occur over many months to years and is particularly heightened in the competitive athlete who has been playing his or her entire life, is usually asymptomatic until clot forms.

Even if we accept that athletes are a special high-risk category for TOS, there remains controversy about the surgical therapy for nTOS. This is fueled by rather poor long-term functional results for surgery, which likely stem from a number of factors, including difficulty in diagnosis, lack of uniform indications, and lack of objective outcomes metrics after surgery.[23,24]

Interestingly, we did find a subset of athletes with nTOS who had a modest improvement in their nTOS symptoms after PT who were offered surgery but declined and continued with PT. Seven of these nine patients (78%) were able to return to their sport in long-term survey follow-up, even though they had not undergone surgery. This group, however, might be different. This nonoperative cohort started with a lower QD baseline score and had symptoms for a significantly shorter period (3.0 months vs 15.1 months), indicating they likely had a milder form of nTOS. This finding that a shorter time of symptomatology might respond to TOS-specific PT with excellent return to sport highlights the importance of early recognition of TOS in the athlete. Education of athletic trainers and the sports medicine staff at the high school, collegiate, and professional levels is an effort we are actively pursuing.

Another interesting finding is the continued improvement in symptoms with time after surgery (Fig 2), as shown by even lower QD scores on the follow-up survey. We attribute this finding to the continued postoperative conditioning and strengthening associated with training and PT and to the makeup of these high-performance athletes. This continued improvement long-term was not seen in our prior publication.

Similarly, the shorter duration of symptoms as it relates to long-term ability to return to sport might be a contributing factor for the PSS athletes doing so well after surgery. Most athletes present with this issue acutely, and the mean time to treatment of 1 to 2 months is typical with early recognition of symptoms. Those athletes who received prompt thrombolysis, clearance of the clot burden, and expeditious surgical decompression were able to recover relatively pain-free and return to their sport at full activity within months. After our group had initially championed a nonoperative role for certain PSS patients, we strongly believe the young athlete who develops PSS must have surgical decompression to maximize the likelihood to return to sport without fear of recurrence or symptomatology.[25-27]

The only other major report of athletes with TOS is from Washington University and describes outcomes in 32 athletes with PSS.[5] Similar to our excellent results with PSS patients, all 32 of their patients resumed unrestricted use of the upper extremity, with a median interval of 3.5 months. They used a multidisciplinary approach based on early diagnostic venography, thrombolysis, and tertiary referral, paraclavicular thoracic outlet decompression with external venolysis, and frequent use of subclavian vein reconstruction, and temporary postoperative anticoagulation with or without an adjunctive arteriovenous fistula. The authors concluded that excellent outcomes could be achieved, even for the challenging patient population of athletes, by using a standardized multidisciplinary approach.

The best outcome in the care of competitive athletes with all forms of TOS appears to require involvement of specialists in sports medicine, orthopedics, physical therapists, team physicians, and individual athletic trainers. In treating our cohort of athletes, we have adopted this approach, maintaining close collaborations with our team physicians, trainers, therapists, and sports medicine colleagues.

Our study has a number of limitations, as with all retrospective reviews. First, although some patients in the nTOS cohort were nonoperative, it was not a true control group because we did offer them surgical intervention and observed that even without surgery, they improved at a very high rate and returned to sport. Only a randomized trial could elucidate the true effect of longer regimens of PT, although likely impractical given the nature of this patient cohort.

Second, along the lines of a lack of a control group for the PSS patients, we have been aggressive about offering young patients surgery based on our previous work,[26,27] so again, there is the possibility that many of the PSS

athletes might have returned to sport symptom-free after thrombolysis, without rib removal.

Finally, the ability of patients to recall many of the timeline improvement issues on long-term survey phone questionnaires is based on their recollections, and because most of them did have a positive result, it is possible there is bias in their answers. Fortunately, verification of return to sport was made more accurate by having box scores, records, and stories about these athletes, which we located on the Internet or were provided by the teams/players. Still, this is lacking objective testing of their overall return to sport performance that could not be recorded.

CONCLUSIONS

We have documented favorable outcomes for treatment of high-performance athletes who present with venous or nTOS. Standardized treatment algorithms, prompt diagnosis and recognition, TOS-specific PT, and selective surgical management can lead to 80% to 90% of high-performance athletes returning to their prior level of competitive sport.

AUTHOR CONTRIBUTIONS

Conception and design: VC, CL, JL
Analysis and interpretation: VC, JL
Data collection: VC, CL
Writing the article: VC, JL
Critical revision of the article: VC, JL
Final approval of the article: JL
Statistical analysis: CL, JL
Obtained funding: Not applicable
Overall responsibility: JL

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DISCUSSION

Dr Hugh A. Gelabert (*Los Angeles, Calif*). I thank the Society for the honor of discussing this presentation. I thank the authors for kindly providing me with their manuscript in a timely manner so that I could review it.

The authors have presented a series of thoracic outlet cases which include both neurogenic and venous presentations. In all, there were 27 neurogenic cases and 14 venous cases, for a total of 41. Of the 27 neurogenic patients, 9 patients were managed

with physical therapy alone and 18 patients underwent supraclavicular decompression. Overall, 22 (81%) of the 27 returned to full activity. On late follow-up, three athletes were disabled by late recurrence resulting in a 66% return to competition rate. Of note, all nine of the nonoperated patients improved although it is not clear if they all returned to competition.

Of the 14 venous TOS patients,13 underwent thrombolysis, 9 (64%) had complete resolution of thrombus, and the remaining 4 (38%) had residual intravenous chronic thrombus. The report indicates that 10 of the 14 patients underwent postdecompression venogram and venoplasty (PTA). Ultimately 13 (92%) returned to athletic competition.

This is a landmark report from our colleagues at Stanford, as it represents the maturation of the TOS program in several ways. They have continued with the use of physical therapy for selection of neurogenic patients for surgical decompression. This is a unique approach to neurogenic TOS. As previously presented to this society, they identify those patients who improve with PT and select them for surgical decompression. For most physicians treating neurogenic TOS patients this was a counter intuitive approach. In this iteration of their experience they reported on 9 patients who improved with PT and did not require surgical decompression. This is an experience more in keeping with the mainstream and might suggest a reversal in the current Stanford approach to neurogenic TOS may be in the offering.

My first question is whether you are reconsidering the use of a positive response to physical therapy as a correct indication for surgical decompression? With regard to the venous patients, the current report represents an even more dramatic departure from past protocol. The Stanford group has previously reported several series that detail their management of venous TOS. Most notable element was a highly selective approach to these patients. They reported at this meeting that only 45% of their venous TOS patients ultimately required surgical decompression. In the current manuscript, *all* venous TOS underwent surgical decompression.

This leads to my second question: what motivated this change in approach? What is your current approach to selection of patients with Paget Schroetter syndrome for surgical decompression?

The authors should be commended on a remarkable report. They incorporates many of the most current approaches to management of these complex, difficult problems and have achieved excellent results. I enjoyed their manuscript and their presentation and recommend it to you.

Dr Jason T. Lee. To answer your questions:

1. We continue to utilize response to PT as the main indicator for offering surgery. While somewhat counterintuitive, this selects out patients who are motivated, have resources and time to get to PT (an important part of the postoperative phase), and suggests that relief of the compression will have some positive response. Even in the nine patients who improved on PT and wound up not getting surgery, we did offer it to them, and in fact their symptoms of onset was a much shorter time period, perhaps suggesting they had a less severe form of nTOS that did not ultimately require surgery for them to return to sport.
2. Selection of patients for vTOS decompression has undergone an evolution at our institution as correctly pointed out by Dr Gelabert. We continue to follow our recommendations from our prior report in 2006 that those patients who were younger (<28) and more athletic all *should* be offered rib resection and venolysis, even with a perfect thrombolysis outcome. We believe the recurrence rate (about 35% over 2 years) is too high for the young athlete to risk, so have become more aggressive about rib resection after PS syndrome.